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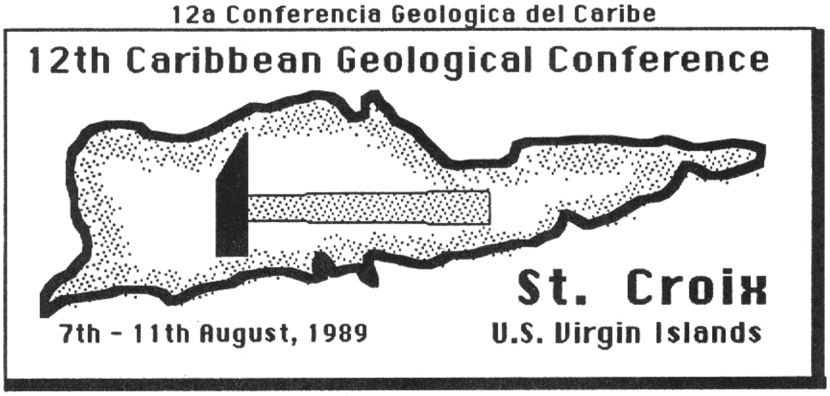

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HURRICANE IMPACTS ON CARIBBEAN BEACHES: THE DEVELOPMENT OF A DATA BASE AND GUIDELINES FOR COASTAL AREA PLANNING AND MANAGEMENT

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ABSTRACT

The incidence of severe Hurricanes in the Caribbean in recent years brings in to focus the need for informed decision making on pre-storm beach protection, coastal planning for beach development sites and post-storm renourishment and rehabilitation measures. This requirement is emphasized by the importance of beaches and the coastal zone in general in economies throughout the region, where tourism and residential development, particularly in the islands, depend heavily on coastal and in particular on beach resources as a focus for activity.

Our preliminary recommendations for data collection and interpretation include observations of the potential or observed tendency for sand bar formation and subsequent onshore migration as a result of storm events, and the time-frame in which this occurs. In addition, the potential for artificial and cost-effective beach renourishment measures at a site needs to be demonstrated particularly for new developments where post-storm sand bar migration may not occur. The development of a vulnerability index for possible hurricane impacts on beaches will be a useful addition to the tool kit of coastal managers and planners.

While recognising the usual constraints of trained manpower, institutional structures and financial resources needed to advance data collection in this area, we suggest that development of a data base and guidelines for management of hurricane affected beaches can be conducted within the framework of existing coastal monitoring projects within individual territories; as part of ongoing regional programs such as the UNEP climate change and IOCARIBE coastal geomorphology projects and that consideration of these problems should be built in to all environmental impact assessment's dealing with coastal area development.

INTRODUCTION

The economic importance of tourism in Caribbean islands is significant in terms of GNP (McElroy and de Albuquerque, 1989), and much of the focus is in coastal areas, where beaches are a, if not the, major tourist resource. In addition, due to physical (topographic) restrictions, major communication routes, residential districts and utility distribution networks are located in low lying coastal areas often adjacent to beaches. Recent record breaking hurricane events such as Gilbert in 1988 (Eyre, 1989) and Hugo in 1989 have highlighted the susceptibility of soft coastal substrates and their adjacent infrastructure to damage from storm surge and storm waves (Bacon, 1989; Hendry, 1989a). With the possibility of more frequent higher intensity storms due to climatic change (Shapiro, in press) the protection and rehabilitation of beaches susceptible to storm damage will be increasingly necessary.

The problems of inappropriate coastal planning for soft substrates have already manifested themselves in several islands, where inadequate set-back limits have placed coastal structures at direct risk from shoreline erosion. The most alarming example of this is in Barbados, which is currently implementing a US$7 million engineering feasibility study to advise on remedial measures for coasts of the island. Our observations and research following Hurricane Gilbert suggest that some emphasis also needs to be placed on understanding beach responses to storm events in the region. This need is further manifested by:

1. The importance of advising coastal landowner's, particularly those with property, of the likely risks of beach damage associated with hurricane events and whether short-term remedial measures are necessary after storm damage to restore degraded beach profiles. Such information will be increasingly valuable as the traditional winter tourist season is expanded into those months of the year during which hurricane activity normally occurs. It will be necessary to differentiate those beaches that are likely to display a naturally rapid post-storm recovery rate from those that recover slowly or not at all, as a basis for decision-making on whether short-term, expensive sand renourishment is required.

2. Future coastal planning that features beaches as a key resource, such as in a

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residential or hotel development should take potential hurricane-related beach damage into account. Far more guidance than presently provided is required, particularly when it is recognised that storm activity is an important mechanism for shoreline retreat under the rising sea-level scenario (Leatherman, 1981; Pilkey *et al.*, 1989; Hendry, in press). This is in addition to other storm-related problems such as flooding and damage to infrastructure from surge and storm waves.

DEVELOPMENT OF THE DATA BASE

While suggesting the need for information on hurricane-related beach changes for applied purposes in the region we are mindful of several major constraints on collection, interpretation and dissemination of data. One is the absence of baseline data on an historical time scale (eg. Hendry, 1979) on beach changes over large areas of the Caribbean. Larger scale pictures of shoreline behaviour over time scales of several thousand years (eg. Hendry and Digerfeldt, 1989) provide useful indicators for long-term shore management, but the site-specific surveyed or photographic data required for detailed local understanding and predictions are generally missing, especially in the context of high-magnitude, low-frequency events such as storms.

Equally important is the availability of personnel within regional Governments trained in observation of beach changes who regularly monitor them and take note of hurricane impacts. In addition, variability in application of descriptive and reporting techniques may reduce the value of observations made following storm events (Hendry, 1989a). This problem cannot be easily solved, except by improved training and the recognition by regional governments of beach management problems to the extent of providing full-time monitoring capability, such as with the Coastal Conservation Unit in Barbados. It is illuminating that the recently conducted Country Environment Profile in Jamaica (I.I.E.D., 1987) only mentioned hurricanes in the context of coastal stability in reference to one location in the north-west of the island. While there are many factors that may influence beach stability at any location, there is clearly a requirement for greater recognition of possible storm impact's at the Government level.

INFORMATION REQUIREMENTS

In order to answer questions as to vulnerability and relative effects on beaches of hurricane attack, we suggest the following lines of inquiry. This set of criteria will undoubtedly need refining, but it is a starting point. In several instances, the type of data needed may be readily accessed from, for example, existing bathymetric charts or aerial photographs or literature and records of coastal processes and resources. In some cases, fieldwork will be required and it is highly desirable that wherever possible some sites are established at which observations of pre- and post-storm beach behaviour are monitored, if only by photographic techniques (Hendry, 1989b). An initial approach should perhaps consider only those beaches which are presently of economic importance or for which some form of development is planned.

Potential for Sand Bar Migration

It is well known that some beaches respond to storm events by formation of shore-parallel bars that migrate onshore after the storm, partially or wholly replacing the pre-storm beach profile. This type of response has been observed in Jamaica for both west and east coast beaches (Hendry, 1982; Hendry, 1989a), where, in the west, recovery may be as rapid as 1-2 weeks. The timing of migration is crucial, especially where property owners fear loss of revenue from damaged beaches and are considering artificial nourishment. The following indicators are important in defining beaches that may respond in this way.

Gradient and Depth of Shelf

Basic bathymetric information is the pre-requisite for several of the investigations that follow. Generally speaking, detailed bathymetric information (say on scale of 1:12,500 or larger) is only available in the Caribbean for areas of interest to marine navigators such as at entries to ports and harbours, though coarser scale surveys are available for most of the region's shelves.

Normal Effective Wave Base

Onshore bar migration will not occur below the level of normal inter-storm effective wave base (depth at which onshore sediment movement can occur), which is dependant on the relationship between shelf bathymetry and characteristics (primarily wavelength) of approaching waves. Sediment deposited during a storm at a depth below this level will not return to the beach. Detailed, local wave climate data are infrequent for the region, but an approximation of approaching deep water waves can be had from the shipboard synoptic oceanographic data collected in the National Oceanographic Data Center in the U.S.A. Where fringing, barrier, bank barrier reefs or extensive patch reefs are found on the shelves, allowance must be made in the assessment for wave shoaling and breaking prior to interaction with the soft-sediment substrate inshore of the reefs that may be the site of sand deposition during a storm.

Sedimentary Sinks

There are many drowned rivers and gulleys on the shelves of Caribbean islands and continental margins that trace the course of former terrestrial run-off during times of lowered sea level. These features may be observable from bathymetric charts, but if the charts are not available, a look at coastal topographic maps will identify the landward continuation of such features and will indicate the need for further investigation offshore. Sediment finding it's way into these features during storms will almost certainly be lost to the nearshore system by downslope processes and will therefore not be available for natural beach restoration. Beaches close to these natural sinks are potential high-risk areas for long-term damage.

Beach Sediment Storage

Successful formation of a longshore bar during a storm is partially a function of the volume of sediment available on the beach, particularly the subaerial portion. There are many examples where narrow stretches of sand back directly onto upland, for example old clifflines: if the sand is removed during a storm it may not readily be replaced due to increase in wave energy from wave reflection on the exposed surface. This stage may not be reached if approaching storm waves are sufficiently dampened by effective build up of the offshore bar prior to complete removal of sediments stored in the beach. If the back-beach scarp is exposed, recovery may be slower, if at all. Sand management, discussed below, is important in this context.

Direct Observations

While some good indications of potential beach response may be obtained from the approaches outlined above, wherever possible it is of course best to supplement the data with actual observations of beach behaviour due to storms. Trained beach geomorphologists can often identify features associated with previous storm action on a beach, though it is difficult to place a time scale on the rate of recovery (assuming this has occurred) if the observations do not follow soon after the incidence of damage. A useful additional source of data are local's, who qualitatively often provide very helpful observations on natural processes, even if the reason and manner of their observation does not follow solid scientific principles. As we recommend elsewhere in this paper, an attempt to incorporate at least some critical sites in future or ongoing beach monitoring programs should also be made by responsible agencies.

Potential for Artificial Renourishment

Where it is established that natural restoration of the beach profile does not occur (or appears unlikely to occur) after a storm, the possibility of artificial renourishment must be considered, though strong words of caution are clearly necessary based on the experience of expensive and not always successful renourishment programs in the U.S.A. (Pilkey, 1989). In the latter cases (Pilkey, 1989), the major problem appears to be that engineers have not always taken the incidence of storm activity into account in the design life of artificial shorelines. In our discussion, we are contemplating this as an option for beaches that we recognise as having potential to suffer long-term storm damage. In these cases, economic forecasting for cost of the renourished beach must take into account a realistic recurrence interval for potentially damaging storms. In the case of beach loss in front of existing property, the landowner, particularly a hotelier, may opt for soft engineering renourishment options even if only to satisfy short-term occupancy and to avoid possible law suits from visitors who have been attracted by brochures that display sandy beaches. It is in any case incumbent on the coastal scientist and engineer to advise appropriately on the potential long-term viability of the post-storm renourishment option.

Offshore Availability of 'Lost' Sand

Although sediment may be lost from the beach to sub-wave base shelf locations during a storm, it may still be close enough and shallow enough to consider dredging or pumping the sediment back to the beach (versus other sources). Clearly cost/benefits must be evaluated, as well as environmental consequences of such operations, though the latter *prima facie* may be hard to argue following a major perturbation such as a storm which moved sediment to that location in the first place. It will be interesting to see the discussions that might be generated on the relative impacts of the event that caused the beach loss versus the engineering process recommended for restoration. It may well be that these locations are also sites for storage of sediments that are lost by incremental processes from retreating shorelines, and again in this context their merit as borrow for renourishment needs to be evaluated against hard engineering options or alternative borrow sites.

Onshore Availability of Storm-Deposited Sand

Where berm overwash takes place during a storm sediment may be moved from the shoreface to the back beach area. It will thus be lost to the active shoreline, a process which may assist in overall retreat of the water line and beach face. This is clearly the most readily available and cheapest source of sand for immediate replenishment of the degraded beach profile. Sadly, poor sand management practices frequently result in the permanent loss of even this sediment to the beach system: following hurricane Gilbert in Jamaica, for example, the authors observed two sites where this occurred. The first was a north coast development project, where sediment transported by storm waves from the shoreface onto an access road behind the beach was spotted by others and illegally removed to other locations by truck. The other was on the east coast, where beach sand blocking the main coastal road was trucked away from the site to restore access to the area.

Other Sediment Sources

Few Government's in the region have adequately addressed the problem of demand for sand in the aggregate and construction industry, or in beach management and maintenance. Sand stealing is still a major problem, in rivers as well as from beaches or adjacent dune areas. Deane (1987) points out that successful implementation of beach protection ordinances in the Lesser Antilles has only taken place in Barbados and Antigua where alternative sources of sediment have been delineated. Against this background, Governments must urgently seek, identify and legalize sand sources that may be used not just for post-storm beach rehabilitation, but for other beach management projects. Regardless of legislation and enforcement, coastal landowner's will find an alternative source to re-build their beach if the need is great enough, and illegal practices will continue until these needs are met. In the context of this paper, coastal researchers and agencies responsible for beach management in the Caribbean must continue to apply pressure for improvement of this contentious problem.

Long-Term Observations of Beach Behaviour

We have already recognised the limited resources available in the region for beach monitoring, but where such projects are in progress, and also at specific development sites where EIA data is required, ongoing observations of beach behaviour can provide valuable input to the coastal scientist's understanding of shoreline response to potential storm events, and on ways in which pre- and post-storm planning can take account of them. The mechanisms responsible for, and the rates of longshore and onshore-offshore sediment transport associated with inter-storm processes, combined with an understanding of sediment sources for the coastal area under consideration give useful clues to storm response and recovery.

VULNERABILITY INDEX AND PROJECT IMPLEMENTATION

In assembling data on storm effects on beaches that can assist coastal planners, managers, developers and landowners some expedient form of technical communication such as a 'vulnerability index' could be developed. Such indices are already well advanced for other purposes in coastal protection, including one for global coastal hazards associated with sea-level rise (Gornitz and Kanciruk, 1989). In the latter case, the data base requirements include information on 1) coastal relief (elevation), 2) rock type, 3) coastal landforms, 4) relative sea-level changes, 5) shoreline erosion or accretion, 6) tidal ranges, 7) wave heights and 8) storm frequencies and intensities. While the actual purpose of this particular data base is different, there is great similarity in the types of observations required, and there is much to be gained for an attempt to incorporate the needs of both in the same exercise, thus providing potential answer's to two separate problems at the same time. We do not recommend that the type of index under development by Gornitz and Kanciruk (1989) be used as a substitute for the one we are proposing here which addresses the very specific problem of Caribbean beach management in response to storms effects, but there is clearly complimentarity in the two approaches.

There is also much to be said for any effort to incorporate development of a hurricane vulnerability index into ongoing local and regional coastal research programs in the Caribbean, where assimilation of the data base requirements in routine information gathering will not require too much additional expenditure of effort. Regional programs at the present time include UNEP's Task Team on Implications of Climatic Changes in the Wider Caribbean (Maul, in press) and the Caribbean Secretariat of the IOC (IOCARIBE) programs on Climate and Physical Oceanography (I.O.C., 1987) and a newly developing one on Coastal Geomorphology. Opportunity also exists for research within International Geological Correlation Project #274 on Coastal Evolution in the Quaternary.

With the clear trend towards acceptable environmental standards in regional planning and development projects, spelled out in policy statements by such institutions as the World Bank (Warford, 1989) and Inter-American Development Bank (I.A.D.B., 1987), there is also a need for incorporation of data on hurricane vulnerability in environmental impact assessment (EIA) for coastal zones in the region and we hope that the approaches given an initial airing in this paper will assist towards that end.

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